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ABSTRACT

This paper debates the usefulness and plausibility of the notion of cognitive structures. The cornerstone of the theory of cognitive philosophy is the claim that the epistemic process is mediated by mental representations that constitute both the knowledge base and interpretations of sensory experience of individuals. Cognitive theorists typically distinguish mental representations from symbolic representations in order to avoid problems of reference and interpretation. The paper concludes, however, that the concept of a representation and a symbol are equivalent, and neither can fully specify or self-interpret. The conclusion that the representational view of cognition is a scientific dead end does not bode well for the application of cognitive theory to educational problems. It is argued that scientific progress in the domain of cognition requires a distinction between symbolic and specification information. The significance of the distinction lies in the fact that at least some of the knowledge that individuals acquire must be obtainable independent of cognitive interpretation or mediation. If the epistemic process is to be understood, focus should be on determining the information present in experience and how that information is processed symbolically by the learner. A 41-item list of references is included. (SLD)

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Mental representations: Reopening the debate

Paper presented at the 1991 AERA convention

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Abstract

Cognitive psychology has come to dominate contemporary psychological thinking in theory as well as practice. The cornerstone of cognitive theory is the claim that the epistemic process is mediated by way of mental representations which constitute our both our knowledge base and our interpretations of sensory experience. Cognitive theorists typically distinguish mental representations from symbolic representations in order to avoid the problems of reference and interpretation. This approach is fundamentally flawed, however, because the distinction proves to be a non-distinction, and because symbols cannot meaningfully self-interpret. The representational view of cognition, in its present formulation, represents a scientific dead end. This conclusion does not bode well for the application of cognitive theory to educational problems. It is argued that scientific progress in the domain of cognition requires a distinction be drawn between two kinds of information: symbolic and specificational. The significance of the distinction lies in the fact that at least some of the knowledge we acquire must be obtainable independent of cognitive interpretation or mediation. Otherwise we could neither learn new concepts, nor distinguish between knowledge and mere figments of the imagination. If we are to understand the epistemic process, we must begin to consider the degree to which the information present in experience specifies as just as important a factor as how that information is processed symbolically by the learner.

I want to reopen a debate; one that, although to my mind crucial, was never satisfactorily concluded. The debate, as published in Volume 18 of the Educational Psychologist in 1983, focused on the concept of cognitive structure. More specifically, the debate centered on the question of whether the process of acquiring the knowledge constitutive of a discipline required one to construct the appropriate set of cognitive structures representing a state of expertise within a particular domain. Like Phillips, the author of the lead article in the debate, I too wish to question the usefulness and plausibility of the notion of cognitive structure. My concern, however, is more general.

Before I begin, I want to make an admission. I have for a number of years been completely captivated, as well as baffled, by a single question: **What exactly is a concept?** I know what the philosophy books say, and I know what psychologists say, and have said. I would not have you think me ignorant. But, I remain baffled. To make matters worse, I think you should be baffled too! I am convinced that we are not going to be able to explain how concepts are learned, or acquired, until we can figure out what they are first. That's because whatever definition we decide to adopt is going to have a lot (if not everything) to do with the kind of explanation we produce. That this is so is clear to anyone who takes a close look at the definitions and explanations we have managed thus far. If, for example, we define concepts as mental representations or structures, we must generate an explanation of how such structures get constructed, stored, reconstructed, recalled, interpreted, etc. In other words, our explanation of concept acquisition will involve the detailing of some fairly complex cognitive (internal) machinery. This seems to

be what has happened in our field in recent years. Is it possible that our conception of cognitive mechanisms has become too complex?

It is not my intention to suggest that the shift from a behaviorist to a cognitive orientation (Rickards 1978, Wittrock 1978) has been a bad thing. I don't think we ought to turn our theoretical clock back to some behaviorist version of the good old days. But, I do think that cognitive theory, as it is presently constituted, presents us with some challenging dilemmas of its own which we are going to have to resolve if our science is going to progress. Not the least of these dilemmas is the problem of defining concepts in terms of mental representations (or cognitive structures).

Having said this much, let me try to state the dilemma, as I see it, as simply as I can: If, as I think cognitive theory clearly demands, **all** forms of cognition are necessarily founded on the capacity to construct valid mental representations of external states of affairs, then the acquisition of knowledge must either be pure magic, or impossible. In other words, as far as a rational theoretical underpinning for our educational prescriptions based on cognitive psychology is concerned, we haven't got one. The reason lies in the nature of mental representations or, more generally, the contemporary representational theory of mind (Fodor 1981b, Haroutonian 1983) that underlies cognitive psychology and treats all forms of knowing as mediated by means of mental representations.

If we read discussions of this topic in the literature we find that an attempt is made to distinguish **mental** representation from more familiar forms of **symbolic** (broadly construed) representation like language, pictures, maps, etc. Mandler (1983, p. 421-422), for example, has argued that there are two

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legitimate senses of the concept of representation and that the sense in which cognitive theorists employ it "refers to knowledge and the way in which it is organized." Furthermore, she posits the claim, in the same article, that "as just discussed, the use of representation does not imply a symbolic, referential, or communicative function", but that, nevertheless, "such knowledge constitutes our model of the world" and that "this model, our knowledge base, is the only information we have about the world." **Mental** representations, in other words, are to be carefully distinguished from, **symbolic** representations. Now, this is an important point because symbolic representations, although wonderful tools, are inherently limited in an epistemic sense. That is, although they can convey knowledge (perhaps I should say information) to anyone capable of interpreting them, they certainly do not constitute knowledge in their own right. Said otherwise, symbols cannot, by definition, be self-interpreting. This seemingly reasonable conclusion, however, is actually at variance with cognitive theory. As Dennett (1978) has so ably shown, for cognitive theory to work, mental representations must be viewed as self-interpreting. That is, at least some very important subset of our mental representations must be such that they are able to "understand themselves" (Dennett 1978, p.275).

I have no quarrel with the claim that we can, and frequently do, generate representations (hypotheses, theories, models, maps, paintings, texts, etc.) of the world which may be said to constitute, in a derivative sense, an objective "world" (domain) of represented knowledge (Popper 1972). It is our ability to generate such cognitive products that is largely responsible for our ability to educate, and otherwise share knowledge with one another. I

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must, however, admit to some confusion when I am told that our knowledge is at once like a representation (a model, theory, etc.) and not like a representation. What, I am inclined to ask, is so special about **mental** representations that makes them different from other types of representations? Bluntly stated, as far as I can tell, the only difference is that we have attached the label **mental** to them. But, perhaps I am being unfair. Perhaps there is a way in which mental representations are different. Before we approach that question, however, I think we need to consider the issue of what exactly representations are a bit more fully.

As Howard (1980) points out, there are many varieties of representation. Representations, may, for example, depict, express, exemplify, describe, speak for, etc. Such distinctions are based on the different functions that various kinds of representations can perform. Representations may also take a variety of embodiments. They may take the form of abstract symbols, of people and/or other organisms, of models or replicas, etc. Perhaps in their most general sense we can say that representations stand for whatever it is they represent. Approached in this fashion, we see that the meaning of the concept of a representation is very similar to what we mean by the concept of a symbol. For all practical purposes, I think we can safely conclude that, in a general sense, the concept of a representation and a symbol are equivalent. Represent is what symbols do, and representations, whatever their form, symbolize, that is, stand for something else, be it person, place, thing, or pure abstraction. Furthermore, as far as cognitive theory is concerned, we might as well go on to conclude that mental representation and mental symbol are equivalent terms. In fact, that is precisely what leading proponents of the cognitive approach

have suggested.

Newell and Simon (1981), for example, have advanced the claim that any system capable of intelligent action is a physical symbol system, that is, must, of necessity, be able to store and manipulate symbols. From their perspective, "Symbols lie at the root of intelligent action" (Newell & Simon 1981, p. 37). Fodor (1975, 1981a) has taken this notion to its logical conclusion by arguing for the necessity of a universal language of thought (LOT). As he puts it, "quite independent of one's assumptions about the details of psychological theories of cognition, their general structure presupposes underlying computational processes and a representational system in which such processes are carried out" (Fodor 1975, p. 28). The notion that cognition is comprised of computational processes operating over mental symbols in the sense of an internal mental language is not limited to the perspectives of Newell and Simon, and of Fodor. It is, in fact, despite a host of other differences in terms of strategy and opinion, a notion widely shared by contemporary cognitive scientists (Hunt 1989). Thus, as far as cognitive theory is concerned, the equating of mental representation and mental symbol seems quite on target.

It would also appear that the roles mental symbols play are some of the same roles that the more familiar types of symbolic representations ordinarily play. Mental symbols, in other words, are employed in the process of constructing (abstract) models of ostensible states of affairs in much the same fashion that we use words, or numbers, or codes, or representational schemes in general. This conclusion may not strike one as overly dramatic or threatening. However, if there is no essential or, for that matter, practical

difference between mental (internal) symbols and other (that is, external) members of the class of symbols, then the former must be subject to the same limitations as symbol systems in general. Specifically, as is the case with other symbols, they can neither fully specify nor self-interpret. Representation, as traditionally understood, is not a useless concept because it presupposes an interpreting agent or entity for whom it serves its designated function. This, of course is the crux of the matter, and explains why Dennett has proclaimed it a necessity that mental structures be self-interpreting if they are to play the role that cognitive theorists wish them to. The question thus becomes (at least, this is the way in which I want to approach the issue): **Are self-interpreting symbol structures possible, and do mental representations have this quality?**

It is clear that Dennett, among others, thinks that "perhaps the prima facie absurd notion of self-understanding representations is an idea whose time has come" (Dennett, 1978 pgs. 274-275). The legitimacy of this claim is founded on an analogy between human cognition and the processing of symbolic information by computers. To quote Dennett (1978, p.275): "For what are the 'data structures' of computer science if not just that: representations that understand themselves?" The assumption that such structures exist is, in fact, present in Newell and Simon's aforementioned discussion of intelligent systems as necessarily being physical symbol systems. Such systems will display intelligence, according to Newell and Simon, if the expressions formulated by the system are capable of, what they refer to as **designation** and **interpretation**. Designation occurs if "access to the object via the expression has been obtained" (Newell & Simon, 1981, p.40). That is, a designating

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expression must indicate an object in terms of further expressions which ultimately designate processes which the system is capable of executing. Interpretation occurs when, and if, the system executes the processes so designated. What is being said, then, is that **mental** representations are control structures, much like computer programs, which exercise causal control over the behavior of a system. This, I think, is the crucial notion that lies behind the claim that **mental** representations are to be differentiated from **symbolic** representations in the traditional sense.

The move made by the cognitive theorist here is, admittedly, both compelling and powerful. However, it is not made without a cost. What I shall argue, and, indeed think is true, is that such a scheme can be made to work, but only as long as we remain within the "reality" of a system of symbols. That is, it is quite possible to create a representational "world", or model, in which expressions (symbols) hooked together in the right sort of way and given physical instantiation can be self-interpreting in Newell and Simon's sense. It may even be the case that, by design, the representational model will be isomorphic to some useful and crucial aspects of the actual world it ostensibly represents. The latter point makes no difference, however, to the computational mechanism which carries out the operations on representational structures which the class of expressions it accepts designate. It is, in other words, a purely formal mechanism which need not concern itself with the meaning of the expressions it receives, or the operations it performs, in relation to external states of affairs (Fodor 1981b). Meaning (interpretation, purpose, etc.) is the concern of the user of the mechanism. Thus, it may be true that, as Dennett (1978, p. 275), argues, "In a computer,

the command to dig goes straight to the shovel, as it were, eliminating the comprehending and obeying middleman." The computer, however, does not know that it is shoveling, or why; nor need it know this to perform its function! What, in any event, does any of this tell us about human cognition or intelligence apart from the fact that we are clever at designing machines to perform work for us? In short, the apparent ability of physical symbol systems such as computers to self-interpret and act intelligently turns out, upon analysis, to be merely a reflection of the skill and understanding of the computer programmer coupled with the "mechanical powers provided by the computer's processing capacity and the computational power of his formal theory" (Shanker 1987).

The consequences of this conclusion are severe as far as current theories of cognition are concerned. Despite their computational speed and ever increasing memory capacity, information processing machines are not cognizant. Nor are they capable of cognitive "growth" in the sense that psychologists and educators are interested in. Formally, and systemically, the conceptual and operational power of such mechanisms is closed. That is, "In a computer model of some aspect of cognition, the intrinsic generation of new primitives is precluded. A system operating solely in the discrete mode cannot self-complex" (Carello, et. al., 1982, p. 233). It cannot, in other words, increase or grow, in terms of representational and computational power. As a result, a severe form of nativism is imposed as an **a priori** constraint on the construction of theories of human cognition grounded in cognitive metatheory (Fodor 1980, Haroutunian 1983). Cognitive theorists can, and sometimes do, disown the computer metaphor (Mandler 1985). However, this is actually beside

the point. It is not the computer as metaphor per se, that is responsible for the shortcomings of cognitive theorizing. Rather, it is the underlying notion that computers and human beings, in their cognitive aspect, are members of the class of physical symbol systems as presently defined by the community of cognitive scientists, that is to blame.

The contemporary conception of cognition as information processing is a limited one. None of the aspects of human cognition we value (understanding, judgement, awareness, etc.) are actually explained by it. Essentially, its limitations can be traced to the claim that **all** forms of cognition are founded on our ability to generate and manipulate mental representations, and by the corollary supposition that information is restricted to the symbolic mode or form. If we are to advance beyond these limitations, and extend our understanding of human cognition, our conception of cognition must move beyond these fatal restrictions. It is time, I think, that we come to understand the real role, including its limitations, of our facility for the use and development of symbol systems. Perhaps this will allow us to appreciate anew those capacities we possess that allow us to acquire knowledge independently of mentation in the symbolic sense. In short, what is needed is a framework for investigating human cognition that neither denies our capacity for representational thought, nor limits our conception of cognition to that form alone.

What I have thus far argued is that the conception of cognition as comprised purely of computations over representations is a severely restricted conceptual and methodological framework. **We** do not exist in a reality of symbols, even priveleged symbols construed as conceptual universals, alone.

The only way in which systems restricted to operating in the symbolic mode could survive, let alone contemplate their existence, within the context of the complex and dynamic biological and cultural ecology that constitutes human reality, is by making them either prescient or indestructible. That we are able to design and construct mechanisms able to, in a limited fashion, operate **as if** they possessed these attributes is a testimony to our cleverness and the degree of understanding of the physical principles that govern our world we have attained, but it does not explain either. Ultimately, cognitivism, forced to stand alone, is a destructive psychology because it denies that we can, or severely limits our ability to, understand ourselves as epistemic agents. Given this situation, what's a poor psychologist to do? Let me return, at this juncture, to the question of what concepts are, and how they might be acquired.

Psychologists of the cognitive persuasion are given to characterizing concepts as mental representations which capture the essential, or, if you prefer, prototypical features of the objects, events, or states of affairs which they represent (Clark 1983, Smith 1988). Because such representations are (except perhaps in the case of proper names) abstractions (that is, not limited to any given instance but representing an entire class), their nature as existents has proven problematic. Nevertheless, it is not stretching matters much to say that concepts are treated by cognitive theorists as though they actually exist as entities in our heads; more precisely, as neural structures in our brain. Not everyone is happy with this physicalistic way of putting the matter, but the notion that concepts have **locations** in the **storehouse of our memory** is widely accepted (Roedigger 1980) and is but a

quaint way of saying pretty much the same thing. It may be that our nervous system generates representations of our experiences. But, representations for whom? And what precisely determines which set of experiences will produce which set of mental representations? Turned the other way, if mental representations are the causal determinants of behavior, how are specific behavioral sequences controlled, generated and modulated in the face of constantly changing circumstances? What is needed, among other things, is an explanation of both how the selection of representations as conceptual interpretations of stimuli, and the generation of particular patterns of behavior, are specified (Shaw, Turvey & Mace 1982).

We have seen that cognitive theorists approach this problem through the construction of self-interpreting representations. Systems of the appropriate kind will, by virtue of their design, accept only specific types of input (expressions) and, as a result, a pattern of machine states is generated so as to produce a specifiable pattern of output. The whole thing works very nicely, as I have said, as long as the system, and its user, remain within the boundaries of its symbolic reality (its model of the world). However, when we ask such a mechanism to engage independently in an adaptive, dynamic and transactional relationship with a complex and fluid reality (actual world), the problem of specification, as far as such devices is concerned, is complicated enormously. For one thing, the conceptual system of our cognitive mechanism can no longer be solipistically restricted to designating its own internal states, but must interpret its states in relation to external circumstances and vice versa, and it must do so, according to the cognitive theorist, without direct access to the significance of external states of

affairs. Consider, for example, a simple situation, one like those which cognitive theorists are fond of using as examples (Anderson 1985, Siegler, 1986): stopping a car at a traffic signal. It is no great matter to write a simple production system in which actions are "specified" by conditions and which captures the flow of decision making in interpreting input and generating appropriate actions. Such a system, given some built in heuristics and a powerful representational language can perhaps be "taught" how to read traffic signals and generate the requisite action conditions. But in a computer simulation this is a mere game played with symbols in a symbolic reality. Consider this system in the driver's seat learning how to operate a real vehicle in the context of actual driving conditions. The situation is, to say the least, complicated a great deal. Speed, road conditions, weather factors, traffic density, etc., many of which are in a state of flux, must all be considered. Also, one must not only attend to these factors, one must coordinate them with their own movements in order to effect an appropriate action sequence. We see, then, why I have said such systems must be prescient or indestructible and why they are not going to take us very far in terms of explaining how concepts get acquired or learned. Systems of this type have, in fact, nothing to learn. They are, in effect, simulations of the programmer's understanding and cleverness.

I suppose we could simply decide to live with these theoretical limitations as, indeed, some have said we must (see, for example, Fodor, 1981b). Perhaps the **practical** consequences are not overly severe. After all, information processing models of the learning process have proven themselves to be useful in the hands of educationally minded psychologists (DiVesta, 1989, Gagne &

Glaser 1987, Glaser 1990, Glover, Ronning, & Bruning 1990). However, I, for one, am not comfortable with such a purely pragmatic approach and believe we ought to be willing to explore some alternatives. The lesson provided by the failure of behaviorism ought, at least, lead us to pause and reflect. I intend, in fact, to suggest that there is a way to overcome the theoretical limitations of cognitive theory, without having to abandon its strengths. The alternative I have in mind is grounded in a tradition in psychology that has come to be called the **ecological approach** (Gibson 1979, Neisser, 1985, Shaw, Turvey & Mace 1982). Time does not permit me to present a full characterization of the ecological alternative at this juncture, but some of its main features will become evident, I think, in what follows.

The way in which I want to approach the issue in the present context is by building on a distinction that can be drawn between **information in the indicational or injunctional mode**, the mode of symbolic representations, and **information in the specificational mode** (Kugler & Turvey 1984). The origin of the distinction can be traced to the work of James Gibson (1979). Its significance lies in the possibility that unlike information in the symbolic mode, the mode to which present conceptions of cognition are restricted, information in the specificational mode does not require the added step of interpretation. The implication is that, consequently, far less in the way of complex cognitive machinery may have to be assumed. This is not to suggest, however, that doing this kind of science will be simple.

Systems that function solely in the symbolic mode (e.g. computers) must, as we have seen, contain their own interpretation. But such a scheme only works where the system is closed with respect to the level of complexity of

the problems it can address and the behaviors it can effect. Systems operating in the symbolic mode must, in effect, both contain their own description, and are limited to this description. The problem with information in the symbolic mode applied to human cognition is that the dynamic activity of an open system, in its full complexity, cannot be reduced to a symbolic description or prescription (Pattee 1977, 1982). Symbols, when effective, only **constrain**, rather than control, the dynamics of an open system. Symbols, essentially are rules, not natural laws. That is, since they cannot specify processes in their dynamic complexity, they fail to provide a **lawful** basis for such processes. (Kugler & Turvey 1984). We are, thus, once again, faced with the problem of interpretation.

Information in the specificational mode, on the other hand, need not, if Gibson (1979) is right, be cognitively interpreted. That is, since, as he argues, and has been able to empirically verify, it arises as a **lawful** consequence of interaction between a structured and cluttered environment and an active, mobile perceptual system, all that is required for it to become knowledge is for an organism to be able to tacitly apprehend its significance (see, also, Lee 1976, Lee & Reddish 1981, Runeson & Frykholm 1983, Turvey & Carello 1988). Significance, however, in this scheme is not a property that resides in either the environment or the organism per se but in their interaction. "It implies the complementarity of the animal and the environment" (Gibson 1979, p. 27).

In the ecological scheme, information specifies because movement of an organism relative to the layout of its environment reveals both the **structural invariants** (roughly, objects) and **transformational invariants** (roughly, events

or patterns of change) present in, for example, the optical structure **lawfully** generated by objects and events in the presence of light (Gibson, 1979, Michaels & Carello 1981). Returning, for the moment, to the problem of driving, there is good evidence to suggest that the process is visually guided on the basis of a lawfully generated optical invariant: time to contact (Lee 1976). In the context of driving a car, the optical information specifying time to contact apparently has rather specific meanings allowing one to, among other things, regulate braking and stopping under a variety of conditions. Thus, it can be seen that information of the specificational kind is inherently meaningful; it reveals, according to Gibson, what objects and events **afford**.

Affordance is defined by Gibson (1979, p. 127) as what the environment (its objects and events) "offers an animal, what it provides or furnishes, either for good or ill." Essentially, what this means is that given an organism possessed of certain characteristics or properties, objects and events will invite fairly specific and meaningful forms of potential activity and/or engagements. If one is being pursued by an attacker, for example, the presence of a stone of an appropriate size and weight affords both picking up and hurling. No complex cognitive deduction need be involved, only attention and a certain presence of mind.

Information, I think, becomes available to us, over the course of experience, in both symbolic and specificational form. We are not limited to a single mode of cognition. When, concepts are presented to us, however, only in symbolic form, we cannot comprehend them unless we already possess the requisite conceptual background and skill to perform the necessary

translation. But if they are present to us, or can be presented to us, in specificational form, then they may inform us directly and we can incorporate them into the tacit (Polanyi 1966) foundation of our knowledge base. Let me attempt to clarify what I mean with an example borrowed from Piaget (1970, pgs. 16-17).

"This example ...was first suggested to me by a mathematician friend who quoted it as the point of departure for his interest in mathematics. When he was a small child, he was counting pebbles one day; he lined them up in a row, counted them from left to right, and got ten. Then, just for fun, he counted them from right to left to see what number he would get, and was astonished that he got ten again. He put the pebbles in a circle and counted them, and once again there were ten. He went around the circle in the other way and got ten again. And no matter how he put the pebbles down, when he counted them, the number came to ten. He discovered here what is known in mathematics as commutativity, that is, the sum is independent of the order. But how did he discover this? Is this commutativity a property of the pebbles?"

Piaget's response is, no. Commutativity is an abstract principle and hence its apprehension on the part of an individual is a mental achievement, the product of reflective abstraction, as Piaget puts it, rather than of mere perception. But consider where this argument takes us. In order for the concept (**schema** in Piaget's terminology) to be formed, the cognitive system must have built the appropriate representational structure. But, how? What, leads it to construct just this particular conceptual structure? How is the concept specified? If it cannot be specified by the information present to the senses, it must arise from within the system. But such a solution only works if the concept is present already in the mind of the child waiting only for the right sort of stimulus to trigger it (Fodor 1980). In fairness to Piaget, I do not think he would have been happy with this conclusion. However, as Haroutunian (1983, p. 13) has shown, "Schemata have the same function in Piaget's theory as the forms of pure intuition (space, time,) and categories

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of understanding have in Kant's, that is, they are used to organize situations and permit experience. Consequently, they are, logically speaking, prior to experience." Piaget's explanation, rooted as it is in the tradition of representationalism, is tied to a conception of information restricted to the symbolic mode. But might it not be possible that the child's numbering game with the stones actually generated information which **specified** the presence of an invariant?

The stones afford the child an opportunity to play, manipulate, explore, and, in the case we are considering, to count. As the child engages in the counting "game", actively exploring its possibilities, information is being generated; information specific to the invariants present in the event structure of the situation. If an invariant is noticed, the opportunity for concept acquisition is present. The implications of this deceptively simple hypothesis are profound and far reaching. Young children are endlessly engaged in exploratory behavior of various kinds. They are information seekers and gatherers as well as information processors (E. Gibson 1988). A rule does not have to be either consciously or unconsciously represented in the mind for one to detect the presence of an invariant or regularity. Children often behave **as if** they understood abstract rules. Gelman (1980), for example, has, for some years, been documenting the fact that even pre-schoolers appear to have a sophisticated understanding of number and counting principles. But this need not lead us to the problematic and circular conclusion that such rules are present in the child's head determining their behavior. By paying too much heed to the question of what may or may not be in the mind of the child we overlook the rich tapestry of information generated in the ongoing exploratory

behavior so natural to children. Taking an ecological orientation with its emphasis on the nature and quality of the information present in experience provides an antidote to the overemphasis on symbol processing typical of contemporary cognitive theorizing. It also suggests the means for resolving some of the paradoxes (see, for example, Bereiter 1985, Lindner 1990) which plague the cognitive approach. Furthermore, some substantial implications for the instructional process may be drawn as well.

From an ecological perspective, instruction should be focused on the carefully guided pursuit of **exploration**, and the **education of attention** (Michaels & Carello 1981). Exploration often naturally leads to the discovery of what objects, events, actions, skills, symbols, problem-solving techniques, etc. afford. However, just because the informational basis for concept acquisition is present does not mean that acquisition will necessarily follow. Particularly in the realm of complex skills or concepts, the learner's ability to detect and differentiate information must be properly calibrated through the education of attention. An educator must not only insure that the learner is provided with information that specifies the concept or skill in question, but that she or he is in the appropriate receptive state. The task of the teacher is to guide the learner to the brink of learning. I am not, however, simply proposing, as many have before, that learning should be activity or discovery oriented. What needs to happen is that opportunities be created that maximize the generation, and/or presentation, of information specific to whatever concepts or skills we are attempting to teach. To accomplish this we are going to have to pay careful attention to not only what people do in terms of processing information, but the nature, quality and power of the

information we make available to the learner. Does our instruction maximize the visibility of the critical information which specifies the target concept, or do we merely provide indications and/or injunctions?

Cognitive theorists with an interest in instructional problems tend to stress the importance of the learner being able to generate effective representations of the problems she or he may encounter. The quality of the representation constructed, it is said, "determines the efficiency of further thinking" (Gagne & Glaser 1987). The ability to construct effective representations, however, is dependent upon a well developed knowledge base in terms of possessing the requisite concepts or schemas. But is this not a case of putting the cart before the horse? Surely, in order to construct valid and effective representations, one must have good information. It may be true that an experienced, highly skilled individual in a given domain may be able to work with relatively weak information by filling in the missing details deductively by virtue of a well developed knowledge base. It may also be true that even when good information is present a novice not will be able to use it effectively. But children do not enter the classroom as experts in the sense that cognitive theorists typically employ this notion. They are not expert physicists, or programmers, etc. What expertise they do possess is largely tacit in nature. Good instruction will, whenever possible, provide information in the specificational sense (or allow the learner the guided opportunity to generate their own) as well as providing information in the symbolic sense (rule guided instruction). In fact, becoming an effective user of symbols and symbol skills is, I think, as much a matter of learning what they afford, as it is a matter of learning or memorizing (that is,

internalizing) rules of procedure, or problem solving. Symbolic reasoning does not replace perception, it merely magnifies and extends its power. In short, what I think the distinction between information in the symbolic mode and information in the specificational mode tells us is that the best kind of instruction will be oriented toward the complementary development of the education of attention and facility in working with symbol systems, rather than focused, as it is now, on facilitating the development of a single mode. Perhaps if we pay equal attention to the nature of the information present in experience as we do to the manner in which it is ostensibly processed, we will come to understand the most important question of all: **How do the two modes come to work effectively together to promote and constrain the epistemic process?**

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